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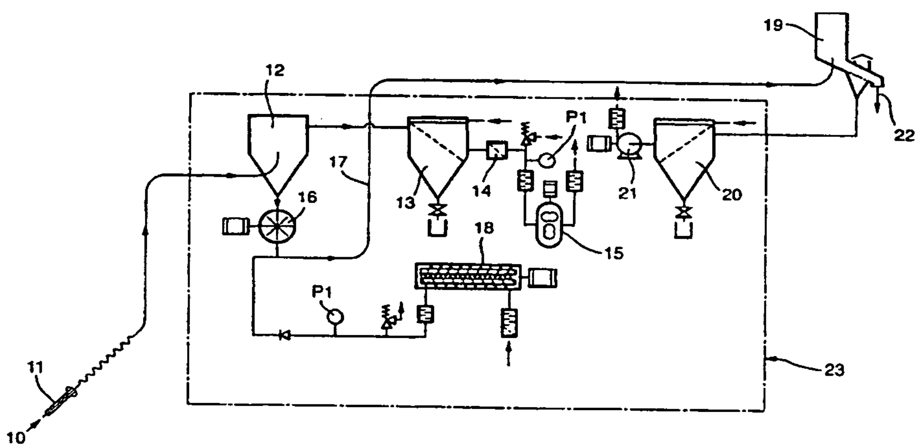

(57) Abstract

An apparatus and method for moving particulate catalyst particles is provided which comprises charging said catalyst from a catalyst source (10) into a feed hopper (12) maintained at a first pressure; transferring said catalyst from said feed hopper (12) into a conveying means (17) which is at a higher gas pressure than said first pressure and which comprises a conduit which communicates with the feed hopper (12) and with a receiving hopper (19), and a means for introducing a gas stream under pressure into said conduit at or near the portion of said conduit which communicates with the feed hopper (12), said conveying means being adapted to convey said particulate catalyst material under dense phase conditions at a pressure greater than said first pressure, and transporting said catalyst through said conveying means by means of a gas stream flowing through said conduit towards said receiving hopper (19) under dense phase transfer conditions to the receiving hopper. The use of dense phase transfer conditions is beneficial in reducing particle damage. The method and apparatus are particularly useful to charge and discharge reactor vessels. The apparatus is preferably transportable.

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MOBILE UNIT FOR TRANSPORTING CATALYST PARTICLES

The present invention relates to an apparatus for use in transporting particulate materials to or from a containing vessel.

The charging or discharging of a reactor vessel typically involves transferring catalyst over relatively long distances, often vertically, because reactors are normally large vessels and may be sited above ground level or in a relatively inaccessible location, depending on the design of the plant. Particulate materials are conventionally conveyed pneumatically, using high velocity air or gas under sub-atmospheric pressure, to or from a containing vessel. This transport method can be referred to as transfer in the lean or dilute phase, wherein the phase density of the particles, i.e. the ratio of the mass flow rate of the particulate material to the mass flow rate of the air used for conveying it is relatively low, e.g. <10, and the particle spacing is relatively high. One of its major areas of usage is within the oil, gas, chemical and petrochemical industries to charge and/or discharge reactor vessels with particulate catalyst materials. The basic principle of this transfer involves the application of a vacuum, in conjunction with a gas stream, to suck the catalyst through a conduit at a velocity typically greater than 20m/s. It is thought that the catalyst travels freely through the conduit and the majority of the conduit is occupied by space. EP-A-0305152 discloses such a method for the discharging of catalyst from a reactor vessel and International patent application W094/24031 discloses such a method for charging a vessel with particulate material.

One common form of catalyst composition comprises solid granules compacted into pellets which may exist in a variety of shapes, for example cylinders, spheres, lobed shapes etc, and in many different sizes and aspect ratios. Such catalyst pellets may be brittle and hence relatively fragile. Therefore they may easily be damaged during the transportation to or from the reactor vessel as they travel through a conduit by impacting themselves upon the walls of the conduit of upon each other. Such damage creates the risk of dust and may also be detrimental to the performance of the catalyst and the formation of a stable catalyst bed. It is therefore highly desirable to convey catalyst materials to the reactor in which they are to be used with as little damage to the particles as possible, whilst achieving rates of conveyance which are comparable to standard methods of conveying catalyst.

Transfer of materials can also take place in the dense phase, as opposed to the lean phase. In dense phase operation, transfer takes place at a lower gas velocity compared with that of lean phase transfer and is under a positive pressure, for example up to 10 bar gauge. In dense phase transfer the particles are typically closely spaced and the phase density in the conveying system is therefore high, typically > about 40. In a lean phase transfer, generally between 3 and 5 tonnes of

particulate material may be transported per hour through a 100mm diameter conduit. For dense phase transfer the rate is typically much greater than this, for example 15-20 tonnes per hour. It is thought that the material travels in discrete masses in the dense phase and is not moving freely at all times. Hence catalyst pellets transported to or from a reactor vessel in the dense phase may suffer less damage and degradation than those transported in the lean phase because movement of the particles relative to each other is reduced, resulting in less impaction upon each other.

One dense phase catalyst transporting system which is known consists of the use "pots" into which the catalyst is charged by means of a pressure filling system, each pot then being conveyed separately to the desired location, e.g. by means of lifting equipment. This process requires filling equipment and lifting equipment to be present at the reactor site and, being a batch process, may be slow. Of course catalyst may also be transported simply by lifting bags or drums filled with the catalyst to the top of the reactor by means of a crane or other lifting gear. This also suffers the disadvantages associated with a batch system and may also be impractical when the site is subject to high winds or other weather conditions which make lifting difficult or hazardous.

It is an object of the present invention to provide an apparatus to convey particulate catalyst material continuously or semi-continuously in the dense phase to and/or from a reactor vessel.

Accordingly the present invention provides an apparatus for conveying a particulate catalyst material from a first location to a second location which comprises:

a) a feed hopper, including means to maintain the pressure within the hopper at a first pressure,

b) a receiving hopper,

c) a conveying means, comprising a conduit which communicates with the feed hopper and with the receiving hopper, and a means for introducing a gas stream under pressure into said conduit at or near the portion of said conduit which communicates with the feed hopper, said conveying means being adapted to convey said particulate catalyst material under dense phase conditions at a pressure greater than said first pressure, and

d) means for transferring particulate catalyst from the feed hopper into said conveying means.

In a second aspect the present invention provides a process for charging and/or discharging a reactor vessel with particulate catalyst which process comprises the steps of

(i) transporting said catalyst from a catalyst source into a feed hopper maintained at a first pressure

(ii) transferring said catalyst from said feed hopper into a conveying means which is at a higher gas pressure than said first pressure and which comprises a conduit which communicates with the feed hopper and with a receiving hopper, and a means for introducing a gas stream under pressure into said conduit at or near the portion of said conduit which communicates with the feed hopper, said

conveying means being adapted to convey said particulate catalyst material under dense phase conditions at a pressure greater than said first pressure,
(iii) transporting said catalyst through said conveying means by means of a gas stream flowing through said conduit towards said receiving hopper under dense phase transfer conditions to the receiving hopper, and
(iv) introducing the particulate catalyst from the receiving hopper into a reactor vessel.

In a preferred application of the apparatus the first location is a container in which the catalyst is located for transport or storage and the second location is a reactor or a charge hopper for a reactor. The apparatus thereby provides a method which is used in charging or discharging a reactor with particulate catalyst material.

The feed hopper is preferably maintained at a low pressure, e.g. atmospheric or sub-atmospheric pressure. The particulate catalyst may be charged to the feed hopper by conventional methods, e.g. by gravity discharge from a container such as a bag, drum or bulk storage tanker etc or by means of a vacuum conveying system as is well known in the art. For example, the catalyst may be introduced into the feed hopper from its container or packaging by means of a vacuum wand connected to a feed conduit which communicates with the feed hopper. This method may be operated under lean phase conditions, but is typically used to convey the catalyst over short distances only so that the catalyst particle attrition may be minimised and solids loading maximised so that particle damage is much less than if a vacuum system is used to convey catalyst particles from the feed location all the way to a reactor loading head. Preferably the pressure is low, for example 0 - 0.5 bar gauge and the gas stream used to convey the catalyst is preferably air. The conveying gas is filtered before passing through a vacuum pump and discharging to the atmosphere. This method may also be used to remove spent catalyst for regeneration from a reactor vessel into the feed hopper. In a preferred form the apparatus includes a vacuum conveying system of the type described above for conveying the particulate catalyst from a container into the feed hopper. When the potential damage to the catalyst particles from any vacuum transfer must be avoided, e.g. in the case of particularly friable particles, it may be preferable to discharge catalyst from its container or packaging directly into the feed hopper and thence into a rotary valve or other conveying means. There is preferably a filter unit present, connected into the hopper feed system, e.g. in series with the feed conduit if used, to separate out any small particles and/or dust at the feeding stage before they are introduced into the feed hopper.

The conveying means comprises a conduit through which a gas stream is passed and which communicates with the feed hopper and with the receiving hopper and a means for introducing a stream of gas through said conduit at or near the end of the conduit which communicates with the

feed hopper. By "communicating with" the feed hopper or receiving hopper, we include indirect communication, for example where the conduit is connected to the respective hopper via an intermediate apparatus such as a valve, filter or particle conveying equipment. The conveying means is adapted to convey said particulate catalyst material from the feed hopper, or from a rotary valve or other intermediate apparatus associated with the feed hopper, to the receiving hopper, or a screen, filter, chute or other intermediate apparatus associated with the receiving hopper, by means of the gas stream under dense phase conditions at a pressure greater than the pressure maintained in the feed hopper. Preferably the gas stream is air provided by a compressor. Other gases may be used if required, e.g. nitrogen, when the catalyst particles are sensitive to air. If the gas is not air or if other conditions, e.g. the toxicity of the particles, require, then a closed system may be used, in which the gas is returned to the compressor, via suitable filtration means, after it exits the receiving hopper. When air is used, a dehumidifying apparatus may be connected before or after the compressor if the catalyst to be conveyed is sensitive to moisture. The gas stream is introduced into the conveying means so as to flow from the portion of the conduit near the feed hopper to the end of the conduit near the receiving hopper. The means for introducing the gas into the conduit may comprise any conventional gas inlet such as a valve, nozzle etc. Preferably a means for controlling the rate of gas flow in the conduit is also provided.

Preferable dense phase conditions are produced when pressures of 0 -10 bar gauge, more preferably 1 - 5, especially 2 - 3 bar gauge are maintained in the conduit such that the velocity of the particulate catalyst is generally less than 20m/s. The particles are conveyed at a velocity which is lower than the fluidisation velocity of the particles to maintain dense-phase conditions of transfer. The fluidisation velocity and thus the preferred velocity of the particles is dependent upon the particle characteristics, e.g. particle size, uniformity, porosity, shape and density. For example, the fluidisation velocity for 5 mm diameter spheres is approximately 18 ms^{-1}. The catalyst particles are generally conveyed at a velocity between 1 - 20 ms^{-1}, preferably 2 - 15 ms^{-1}, especially 3 - 12 ms^{-1}. The calculation of the gas velocity required depends upon the particle type and rates of transfer required but more especially on the conveying means, e.g. the diameter of the conduit, the distance and vertical lift between the feed hopper and the receiving hopper and the configuration of the conduit, i.e. the number of bends. The gas velocity is proportional to the particle velocity. In a typical apparatus, the conduit may be between 5 and 200 m in length, preferably 10 - 100 m, more preferably 10 - 70m. The conduit used is normally between 50 - 150 mm in diameter, preferably 75 - 125, especially about 100 mm. Although the velocity of the catalyst particles is much lower than would be typical in a lean-phase conveying system (e.g. about 30 - 50 ms^{-1}), the rate of bulk catalyst transfer is faster because the phase density in the conduit is greater. We have found, for example, that the apparatus is capable of conveying 4mm spherical particles a distance of 30 m vertically and 50m horizontally at a rate of 15 te/ hour. The relatively low velocity of the catalyst

particles and the fact that they undergo dense phase conditions of transfer means that damage to the particles is relatively low compared to lean phase transfer which uses higher particle velocities but lower phase densities in the conduit.

The means for transferring the particulate catalyst from the feed hopper to the conveying means, which is at a higher pressure than the feed hopper, may be via a pressure vessel or "blow tank" into which the catalyst is transferred and discharged into the conveying means. Although a pressure vessel system can achieve a high instantaneous conveying rate into the conveying means the batch nature of the operation and the need to de-pressurise the vessel before refilling means that the effective overall transfer rate is reduced. This disadvantage may be overcome to some extent by providing more than one blow tank in series. More preferably the means comprises a screw feeder or, most preferably, a rotary valve which allows the transfer to proceed with less particle damage and enables a continuous catalyst transfer process to take place with the consequential greater overall conveying rate than with a pressure vessel system. Other devices, such as gate-lock valves may also be employed but are less preferred. The design and use of rotary valves and screw feeders for transfer of material between locations which are maintained at different pressures is known in the art and the selection of an appropriate rotary valve for the transfer conditions (e.g. pressure) to be used and the quantities to be transferred may be made by an ordinarily skilled person.

The receiving hopper is arranged such that the particulate catalyst can subsequently be transferred via gravity flow into the reactor for the charging process or a suitable vessel for regeneration for the discharging process. Preferably there is a filter unit present to remove any small particles and/or dust prior to the transfer of the catalyst from the receiving hopper to the reactor or the vessel for regeneration. The receiving hopper is preferably designed to minimise particle attrition, e.g. by incorporating one or more screens onto which the particles are discharged or other particle brake equipment. In a preferred embodiment, the receiving hopper contains a screen, preferably of wedge-wire or a similar material which has a positive gas flow though it. Such a screen allows catalyst particles to pass over it but the gas flow tends to entrain dust and other fines included with the catalyst particles and prevent them from entering the reactor. The gas flow through the screen may comprise the gas used to convey the particles from the feed hopper and may also be made up with additional quantities of gas. The conveying gas and any further gas which has been introduced into the system ultimately is discharged to the atmosphere or recycled to the compressor or conveying means, preferably after passing through a filter to remove dust.

The apparatus is preferably mobile or adapted to be transportable, for example mounted on a moveable platform or trailer, or within a moveable container, which may include independent

movement means or which may be towed e.g. by a lorry, tractor, wagon or other vehicle or moved by rail or sea, such that it can be readily transported to a reactor site, thereby to be used in charging and/or discharging catalyst to/from a reactor when required and then moved to a different location when not required. In this form the apparatus is particularly useful in providing reactor charging or discharging services on demand at any accessible location, thereby avoiding the cost of providing fixed catalyst conveying facilities for each individual reactor. The transportable apparatus preferably includes a power source, which is preferably a generator, e.g. a diesel generator, a compressor for providing pressurised gas to the conveying means and all ancillary equipment required to operate the process so that the transportable unit or container is capable of operating self-sufficiently when fuel is supplied to the generator and compressor. In a preferred form the apparatus includes a solids handling system, especially a vacuum conveying system, for charging the feed hopper with catalyst, and the transportable apparatus then also comprises the vacuum wand, vacuum pump and conduit required for such a system together with a power source etc required to operate the system.

The catalyst particles may be charged to the reactor from the receiving hopper by any chosen method, including simple gravity feed into the reactor or by using a specialised reactor filling system or apparatus of the type known in the art. There are reactor bed filling systems and apparatuses available which are designed to produce a reactor bed in which the catalyst particles are uniformly packed without voids which could cause weaknesses and hot-spots in the reactor bed, and which allow the catalyst to fall into the reactor with minimal damage to the particles. Examples of such apparatus are described in GB-A-2287016 and US-A-5247970, amongst others.
When the apparatus and method of the invention is used to discharge catalyst particles from a reactor, the particles may be transferred from the reactor to the feed hopper by means of a vacuum system and then conveyed in the dense phase by means of the conveying means to the receiving hopper which may be mounted over a drum filling station or bulk tank, for example, for transporting the catalyst away from the reactor.

Specific embodiments of the invention will now be further described with reference to the accompanying drawings (Figures 1 and 2) which are schematic diagrams of a transportable apparatus for transferring particulate catalyst according to the invention.

In Figure 1 the particulate catalyst is transferred from a bulk source (10) using a vacuum wand (11) to convey the catalyst, through a conduit with a stream of air at a pressure of 0.3 bar gauge, into a feed hopper (12). Any small catalyst particles are separated out by the application of pressure to suck them into a reverse jet filter unit (13), with a secondary back up filter (14) to trap any dust generated. This is linked through to an exhauster (15). The particulate catalyst is transferred via a high pressure rotary valve (16) with a star feeder into a conduit (17) accompanied by a stream of air

maintained at a pressure of 3 bar gauge via a screw compressor (18). The particulate catalyst is received into a receiving hopper (19) under gravity and dust is separated, by application of pressure into a second reverse jet filter unit (20) with a back up exhaust air fan (21). The particulate catalyst is then transferred to a reactor vessel via gravity flow (22). (23) illustrates a container unit for the mobile equipment.

In an alternative embodiment the catalyst is gravity fed from bags or drums into the feed hopper.

The embodiment shown in Figure 2 differs from that of Figure 1 in that the high pressure rotary valve is replaced by a pressure vessel (24) combined with flow control valves. Valve (25) is opened and valve (26) closed for transfer of the particulate from the feed hopper (12). Valve (25) is then closed and the vessel pressurised to 3-4 bar gauge by opening of valve (27). Valve (26) is then opened for transfer of the catalyst into the conduit (17).

As an example catalyst particulates were transferred as according to the present invention and also by lean phase transfer for comparison. A proprietary catalyst particle in the form of 4mm spheres was conveyed a distance of 50m along 100 mm diameterconduit. The particle velocity was varied by varying the air mass used to convey the particles. The particles were analysed after the experiment by sieving and the % degradation in particles calculated from the material lost from the particles in transit. Table 1 shows the percentage degradation of the catalyst in both the lean and dense phases.

Table 1

Particle Velocity in ms^{-1}	% Degradation
7	0.3
12	1.0
17	1.5
22	1.5
26	2.5
32	4.0
40	9.0
47	19.0
48	25.0

This illustrates that particulate catalyst transported at low velocity via the dense phase is less likely to suffer degradation than that transported via the lean phase at higher velocities.

Claims

1. An apparatus for conveying a particulate catalyst material from a first location to a second location which comprises:

a) a feed hopper, including means to maintain the pressure within the hopper at a first pressure,

b) a receiving hopper,

c) a conveying means, comprising a conduit which communicates directly or indirectly with the feed hopper and with the receiving hopper, and a means for introducing a gas stream under pressure into said conduit at or near the portion of said conduit which communicates with the feed hopper, said conveying means being adapted to convey said particulate catalyst material under dense phase conditions at a pressure greater than said first pressure, and

d) means for transferring particulate catalyst from the feed hopper into said conveying means.

2. An apparatus as claimed in claim 1, further comprising a vacuum conveying system for transferring the particulate catalyst from a container into the feed hopper.

3. An apparatus as claimed in claim 1 or claim 2, wherein a means for filtering dust or particle fines from the particulate material is provided, said means being arranged to reduce the quantity of said dust or fines which enters the feed hopper.

4. An apparatus as claimed in any of claims 1 - 3, wherein the means for transferring particulate catalyst from the feed hopper into said conveying means comprises a rotary valve, a screw feeder or a gate-lock valve.

5. An apparatus as claimed in any of claims 1 - 3, wherein the means for transferring particulate catalyst from the feed hopper into said conveying means comprises a pressure vessel.

6. An apparatus as claimed in any of the preceding claims, wherein the gas stream is air.

7. An apparatus as claimed in any of the preceding claims, wherein said conduit has a length between 5 and 200 m. and a diameter in the range 50 - 150 mm.

8. An apparatus as claimed in any of the preceding claims, wherein a means for filtering dust or particle fines from the particulate material is provided, said means being arranged to reduce the quantity of said dust or fines in the receiving hopper.

9. An apparatus as claimed in any of the preceding claims, which is adapted to be readily mobile or transportable.

10. An apparatus as claimed in claim 9, comprising at least one moveable container, or trailer having arranged thereon:

a) a feed hopper, including means to maintain the pressure within the hopper at a first pressure,

b) a receiving hopper,

c) a conveying means, comprising a conduit which communicates with the feed hopper and with the receiving hopper, and a means for introducing a gas stream under pressure into said conduit at or near the portion of said conduit which communicates with the feed hopper, said conveying means being adapted to convey said particulate catalyst material under dense phase conditions at a pressure greater than said first pressure, and

d) means for transferring particulate catalyst from the feed hopper into said conveying means.

e) a power supply,

f) a gas compressor, adapted to supply said gas stream to said conveying means.

11. An apparatus as claimed in claim 9, further comprising a solids handling apparatus for introducing catalyst particles into said feed hopper.

12. An apparatus as claimed in claim 11, wherein said solids handling apparatus comprises a vacuum conveying system, comprising at least one vacuum wand, a conduit communicating with said vacuum wand and with said feed hopper and a means of inducing a gas flow in said vacuum wand and conduit.

13. A process for charging and/or discharging a reactor vessel with particulate catalyst which process comprises the steps of

(i) charging said catalyst from a catalyst source into a feed hopper maintained at a first pressure

(ii) transferring said catalyst from said feed hopper into a conveying means which is at a higher gas pressure than said first pressure and which comprises a conduit which communicates with the feed hopper and with a receiving hopper, and a means for introducing a gas stream under pressure into said conduit at or near the portion of said conduit which communicates with the feed hopper, said conveying means being adapted to convey said particulate catalyst material under dense phase conditions at a pressure greater than said first pressure,

(iii) transporting said catalyst through said conveying means by means of a gas stream flowing through said conduit towards said receiving hopper under dense phase transfer conditions to the receiving hopper, and

(iv) introducing the particulate catalyst from the receiving hopper into a reactor vessel.

14. A process as claimed in claim 13 wherein the catalyst is transported from the catalyst source to the feed hopper by means of a vacuum conveying system.

15. A process as claimed in claim 13 wherein the catalyst is charged to the feed hopper by means of a gravity feed.

16. A process as claimed in any one of claims 13 to 15 wherein the catalyst is transferred from the feed hopper to the conveying means by a pressure vessel system.

17. A process as claimed in any one of claims 13 to 15 wherein the catalyst is transferred from the feed hopper to the conveying means by a rotary valve, screw-feeder or gate-lock valve.

18. A process as claimed in any one of claims 13 to 17 wherein the conveying means is operated under dense phase conditions at a pressure of between 0 to 10 bar gauge.

19. A process as claimed in claim 18 wherein the conveying means is operated under dense phase conditions at a pressure of between 1 to 3 bar gauge.

20. A process as claimed in any one of claims 13 to 19 wherein the feed hopper pressure is less than 1 bar gauge.

21. A process as claimed in any one of claims 13 to 20 wherein the gas stream is air.

22. A process as claimed in any one of claims 13 to 21 wherein the velocity of the gas stream is selected to produce a particle velocity which is less than the velocity required for suspension or fluidisation of the particles in the gas stream.

23. A process as claimed in claim 22, wherein the velocity of the gas stream is in the range 1 - 20 ms^{-1}.

24. A process as claimed in claim 23, wherein the velocity of the gas stream is in the range 2 - 15 ms^{-1}

25. A process for discharging a reactor vessel as claimed in any one of claims 13 to 24 wherein the catalyst source is a reactor vessel.

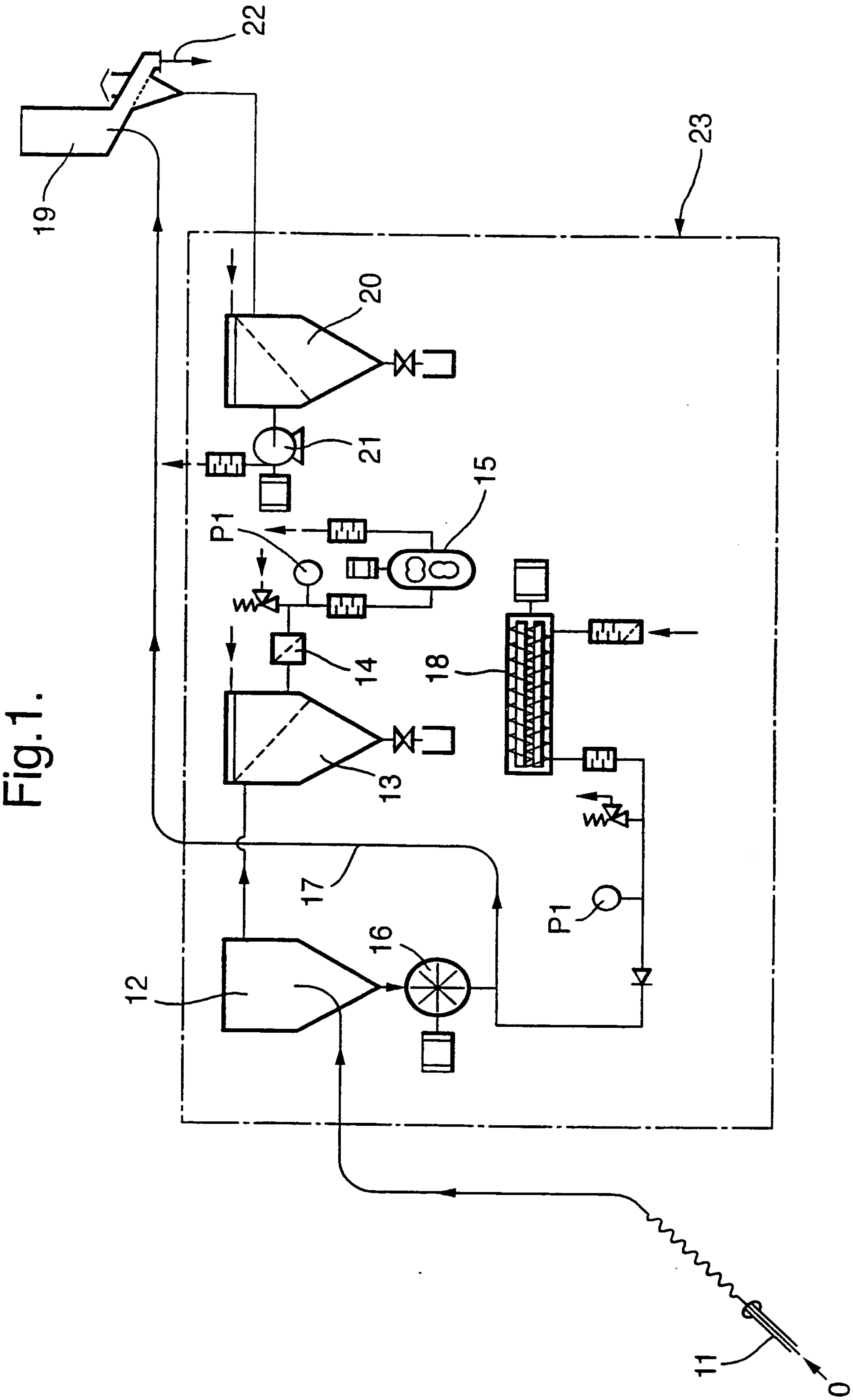

Fig.1.

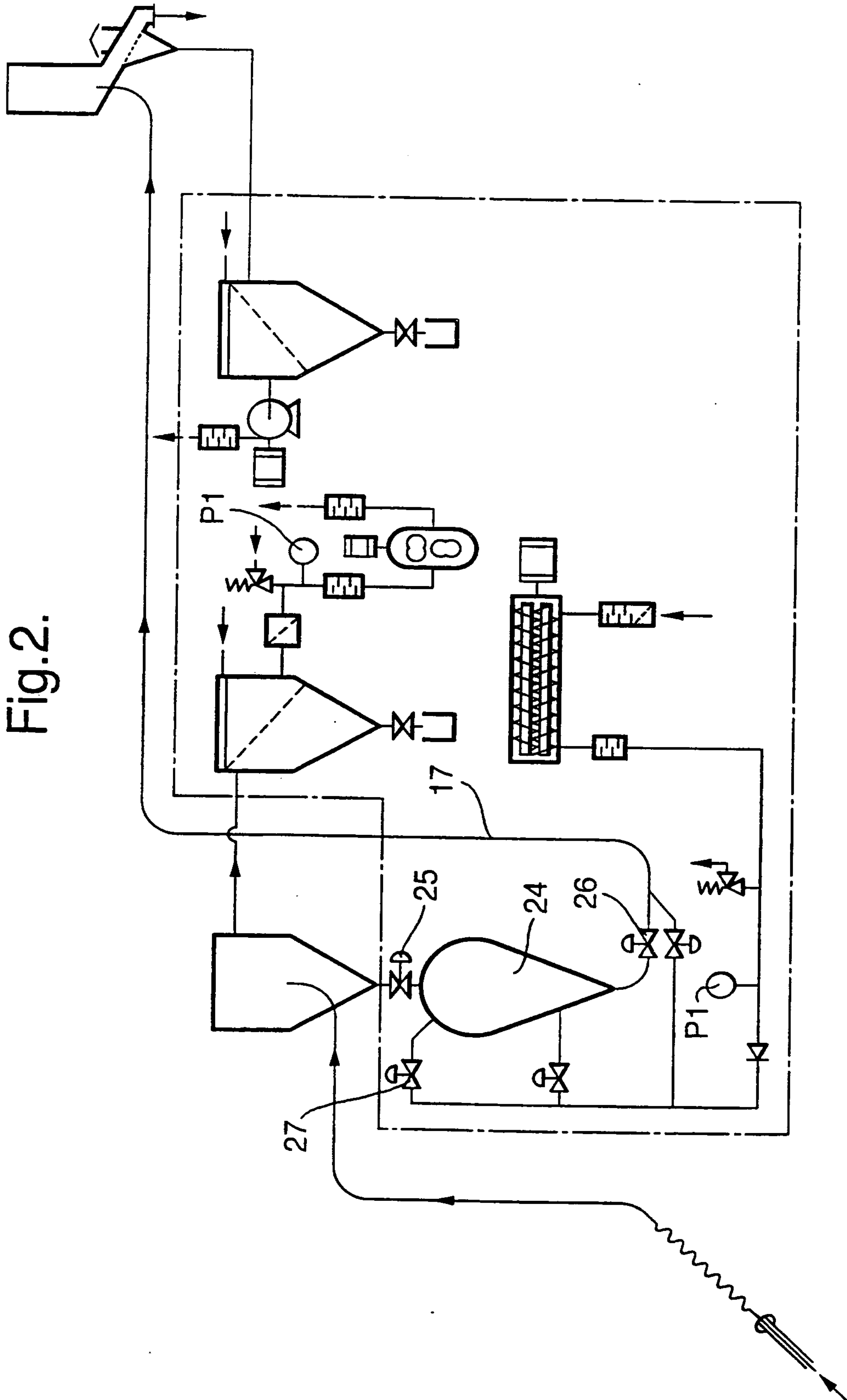

Fig.2.

INTERNATIONAL SEARCH REPORT

Inte onal Application No
PCT/GB 00/00507

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 B01J8/00 B01J3/02

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 B01J B65G

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 4 695 205 A (LEVINE MARC S) 22 September 1987 (1987-09-22) the whole document	1-6,8,10
A	EP 0 648 697 A (SUMITOMO CHEMICAL CO) 19 April 1995 (1995-04-19) the whole document	1,7,13, 18,25
A	US 4 018 671 A (ANDON NICHOLAKI, FLEECE ROBERT I) 19 April 1977 (1977-04-19) the whole document	1,6,13, 15
A	GB 1 427 570 A (BROWN R W) 10 March 1976 (1976-03-10) the whole document	1,4,6,7

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[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

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C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication,where appropriate, of the relevant passages	Relevant to claim No.
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